Using Collaborative Web Sites to Overcome Barriers to Collaboration in Science and Engineering

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Abstract

Initial studies of how Collaborative Web Sites or CoWebs might enhance knowledge transfer between science and engineering classes showed an apparent barrier to student collaboration. This barrier appeared to be related to the culture of many engineering students. Here we investigate how projects that provide a perceived benefit from collaboration may be implemented in engineering classes using the CoWeb. Important results from this investigation suggest collaboration can occur, but some activity to drive the student interaction on the CoWeb must take place. This activity must provide the appropriate grading structure such that learning from collaboration is not penalized and active participation is rewarded. It appears that students with an "Active" learning style, which may be common among engineers, are inclined toward collaboration. The results also suggest that projects involving analysis of realistic data, that is also relevant to the student, might better motivate students.

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I. Introduction

A. Motivation

Previously we have attempted to encourage student collaboration in science and engineering using Collaborative Web Sites or CoWebs [1-3]. Our motivation for encouraging collaboration is to promote transfer of knowledge between classes via both synchronous and asynchronous collaboration [2]. These previous efforts were focused on transfer of knowledge between classes to overcome the tendency of students to compartmentalize knowledge rather than applying knowledge from a previous class to the current one. While initial results were encouraging, we discovered an inherent barrier to collaboration in the chemical engineering classes in which we tested this CoWeb-based collaboration [1]. This appeared to be a cultural issue that plagued engineers specifically. Such reluctance to collaborate did not appear as readily in various computer science [4], architecture [5,6], and English classes [7]. We suspect the origin of this cultural difference is rooted in the way engineering students see collaboration. Most engineering students see the answer to a project or homework assignment as singular; a single quantity, recommendation or basic design. To most engineering students, collaboration simply gives away that single quantity and raises the grading curve. However, students perceive many ways to construct the same computer program, architectural design or English composition. Therefore collaboration is seen as beneficial to the student in these fields.

Recently we have focused our efforts on developing collaborative projects and activities to motivate the engineering and science student apart from the difficulties of managing collaborations across classes. Admittedly, collaborations within classes do not address the aforementioned issue of knowledge transfer, but they do provide additional educational benefits. It is important to teach students effective Web-mediated collaboration in the classroom because industry is currently practicing design in a collaborative fashion over the Web [8-10]. This is likely to become an important skill in the workplace. The importance of collaboration and the use of technology supported learning to improve education is also recognized in chemical engineering education [11]. Clearly, collaborative projects in engineering and science must be made more open-ended so the students do not perceive the answer to be a single quantity or narrowly focused design. Our challenge is to create such open-ended projects to encourage collaboration, while retaining some ability to objectively evaluate such projects. Certainly, more interesting projects can help motivate the students to collaborate. While many such projects, designed to increase student interest, have been enumerated [12], here we discuss projects specifically designed to provide a clearly perceived benefit to collaboration by the engineering student.

B. CoWeb

The CoWeb is an open architecture Web site that is based on the original WikiWikiWeb (or Wiki) by Cunningham [13]. This application was rewritten in Smalltalk by Mark Guzdial and his research group at Georgia Tech. This new application, sometimes called the Smalltalk Wiki or SWIKI is the basis for the CoWeb used in this work. Anyone has the same ability to edit pages or create new pages at any point in this network of Web pages that comprise the CoWeb. While HTML code may be included in any Web page, most of the editing can be done without any knowledge of HTML code. Figure 1 shows a sample CoWeb page and its corresponding editing window that illustrates how new links and windows for appending to pages are produced with simple logical commands. Note that recent changes and history are managed by the *history* and *changes* icons, to insure that recent copies are available in case information is erased through an accidental edit.

While the original CoWeb (or SWIKI) was very useful for creating Web pages and collaborative interaction among students and instructors, there were certain requirements that were added to facilitate ease of use among scientists and engineers. The *upload* icon has been added and expanded because scientists and engineers needed to upload graphs and diagrams for discussion in collaborative work. Also, the lock icon was added for use by instructors to prevent reference material from being erased, and for use by students to limit access to group members for collaborative group projects. The newer version of the CoWeb also prompts the user to confirm the creation of a new page after it has been defined using asterisks in the edit mode. This is designed to eliminate the problem of creating a large number of superfluous pages when the asterisks used in computer code (as multiplication symbols) are mistaken for new pages. In fact, a version of the CoWeb was developed with a special <matlab> tag that formats MATLAB programs for use in applied computing courses.

II. Collaborative Projects

During the past spring semester at Georgia Tech, collaborative projects were carried out in several classes, including a Chemical Engineering Unit Operations Laboratory class (CHE4200

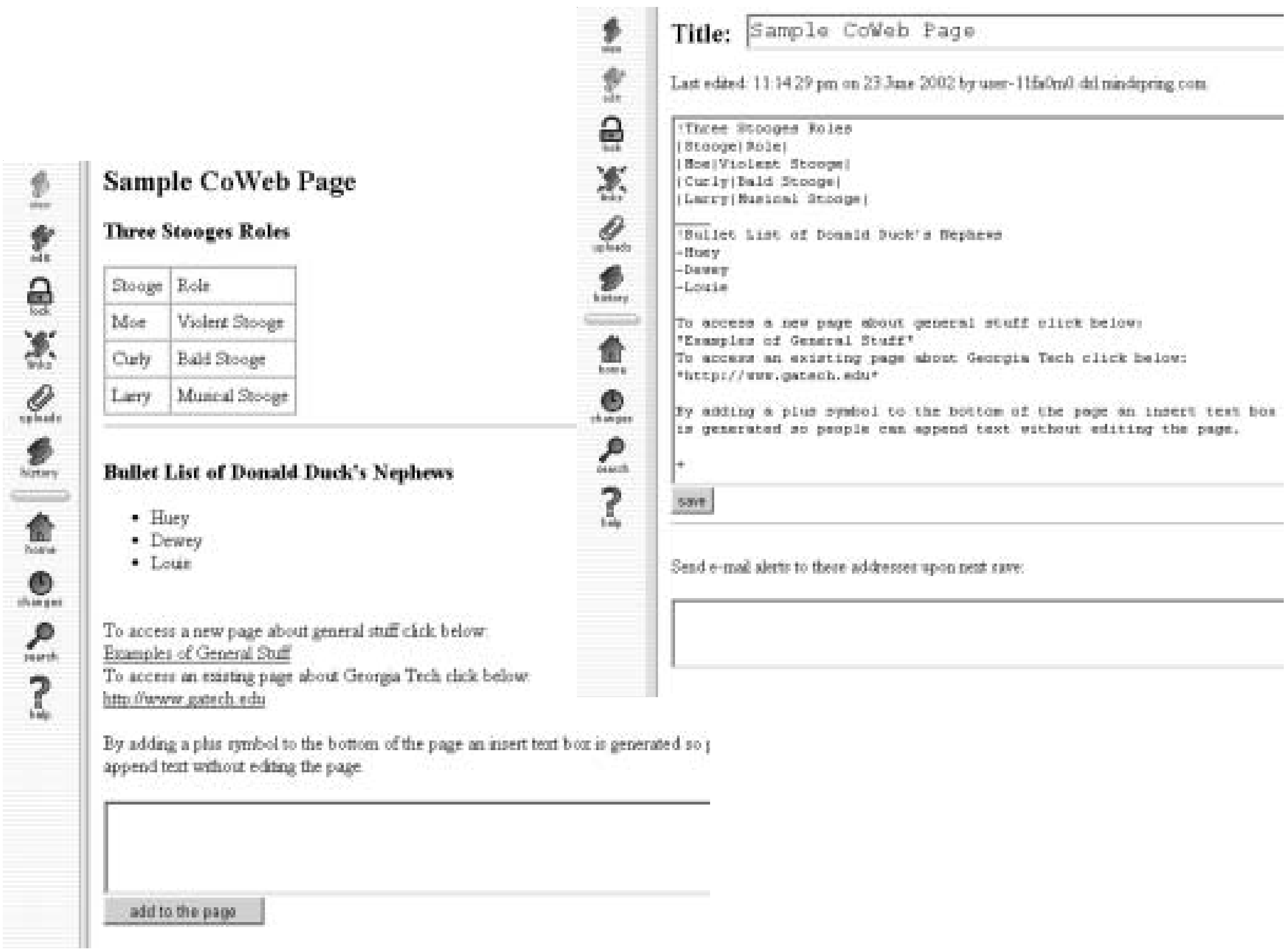

Figure 1. Sample CoWeb page (lower left) and the corresponding editing view (upper right) with the CoWeb source code shown. Note that simply adding a + symbol to the page inserts a window to append text to the page for discussion and interaction.

taught by PL), and Chemical Engineering Process Control Class (CHE4400 taught by MR) and a Calculus class (MATH2602 taught by TM). We will focus most of our analysis on the CHE4200 projects, but observations of the other projects will be discussed as well. The CHE4200 class had two collaborative projects that used the CoWeb.

Historically, chemical engineers divide a chemical process into discrete steps of mixing, reaction, and various finishing and separation steps called "Unit Operations." In this course the students write fairly narrowly prescribed reports on various "Unit Operations" labs.

The first collaborative project consisted of data analysis of a slurry filtration simulation. Unlike the physical lab experiments, where students are limited to a specific set of data by time constraints, this virtual lab provided the students with many options on the amount and ranges of data to be taken, as well as the analysis to be used. For example, they could numerically differentiate the data and fit it to a linear model or fit the raw data to a quadratic model. Using numerical differentiation added noise to the data so more sets of data were often required but the higher-order fit is conceptually more difficult for many students. Each student determined the physical parameters that described the flow resistance of the filter material and the filter cake of solids that forms. The simulated data had a realistic amount of error and an initial transient to introduce realistic fluctuations in the results. In the first part of the project, groups of students analyzed filtration with some of the same filtration material to produce similar results. This allowed them to compare their results with others to verify the accuracy of their analysis. We presumed that most students would have the correct answer and those with spurious results would fix their analysis and the groups would converge to the correct answers.

After collaborating on this first part of the lab, all the groups were to carry out the same simulated experiment using an additive to supposedly aid in the filtration. These were all unique so the students will all have different answers. However, we presumed that collaboration during the first part of the lab should help students remove analysis and unit conversion errors from the their process, thereby producing accurate calculations for the second part of the lab.

The second collaborative project required the students to answer an open-ended analysis or design question about one of the Unit Operations labs and post a detailed report of the analysis on the CoWeb. The students were required to critique each other's CoWeb reports during the first phase of the project. The bulk of the grade for this project was based on the final phase so improving the report based on the reviews of fellow students could be made with very little penalty in the final grade. Examples of these open-ended problems included:

- solving the problem observed with a centrifugal pump lab, where the pressure gauge and torque meter on the pump fluctuated wildly; and
- determining under what conditions, the assumption of ideal mixing was valid for a stirred tank reactor experiment that previously made this assumption.

Another collaborative project consisted of the building of a model to describe the flux of compounds through cadaver skin after the application of chemical agents and electrical pulses (CHE4400). Real data from ongoing research on the ability of chemical agents combined with electrical pulses to enhance transdermal drug delivery was used. Although not known at the time of the project, the data contained an artifact of a variable sampling rate. This sampling rate artifact made the flux a complex function of time, which meant that a number of models could be developed to describe the data. This made the project open-ended with no obvious answer, thereby providing motivation for collaboration. The third collaborative CoWeb project was carried out in a Calculus class (MATH2602) and involved the development of a model to predict a student's weight based on seemingly unrelated parameters such as age and time spent studying calculus. This project used student-generated data with linear correlation.

III. Results and Discussion

A. The Collaboration Process

We assumed that posting results for the simulated filtration lab would automatically produce collaboration among our students. However, we encountered a variation of the Prisoner's Dilemma [14]. In this paradox of rationality and cooperation, the optimal behavior is for two prisoners to cooperate to avoid being found guilty and punished. The equivalent result would be for all students to report the same wrong answer and ride the grading curve. In our case, the students reported disparate answers that provided little guidance regarding the accurate result. It was clear that action must be taken to drive the system to the accurate answer in a collaborative fashion. Our system differs from the Prisoner's Dilemma in that we can calculate an accurate answer for all cases (i.e., the jailer knows who is guilty). The Teaching Assistant posted a reasonable solution on the Web for all conditions in part one of the project. Initially, approximately two thirds of the students had answers that deviated from the expected value by significantly more than the expected fluctuations. Of these students, approximately half did eventually arrive at a more accurate solution in this first part and an accurate solution for the second part of the project where they evaluated the effect of an unknown filter aid. Unfortunately, one third of the students did not benefit from the posted answers, and consequently produced an inaccurate answer which was reflected in their grade for the second part of the project.

The process above illustrates the need for some mechanism to initiate collaboration. We incorrectly assumed that the desire to obtain an accurate answer was sufficient. However, the perspective of the Prisoner's Dilemma decouples the accurate answer from the overriding goal of a good grade. This mechanism should provide a grade bonus for students who do check their answers and challenge those with incorrect answers. Those students or groups who change their answers as the result of such a challenge should not be subject to a grade penalty. Alternatively, this grading scheme should provide a bonus to the groups who prove the initial challenge to be unwarranted, but provides no penalty for the initial challenging group to change their answer. We suggest using the CoWeb to set up such a forum in which inaccurate results are challenged and modified in a collaborative fashion with such an appropriate grading scheme.

B. Assessment of Collaboration

Collaboration in the two projects described above, was assessed using a survey that asked students to rate various statements from 1 (strongly disagree) to 5 (strongly agree). The results of this survey are listed in Table 1. In general, the students appear to find the CoWeb and the information posted therein to be useful. The relatively high mean answers associated with questions 8 and 11 suggested that the students are actually using the CoWeb for student collaboration. The high means associated with questions 15 and 17 suggested that this collaboration may have impacted the simulated (virtual) filtration lab and studying for the final exam the most. The particularly high score associated with question 17 may have been due to lack of any previous exam review activities in this course. The high mean in question 15 reflected the fact that almost two thirds of the students had problems with the original results they posted for the filtration project. Approximately one half of those students significantly improved the accuracy of those initial results before the final project was due. However, it was rather disappointing that approximately one third of the students turned in reports with inaccurate results. The teaching assistant assigned to this project indicated that most of these students ran out of time before they could eliminate the errors from their analysis for the final report.

As we have observed previously, the students still retain some tendency to see the CoWeb as a traditional Web site that acts predominantly as a data depository. This is indicated by the high mean responses associated with question 10. The fact that the mean response for question 8 is just as high is encouraging, but this also suggests that while many students find the student responses useful, only a small number of students are actually posting useful materials on the Web. While such postings were required for the second collaborative project, most of the postings for the first collaborative project as well as discussion about the other labs were posted by approximately one third of the students in the class. However, even as a depository of information, the ease of use of the CoWeb gives it distinct advantages. Traditionally, many of the faculty in the School of Chemical Engineering at Georgia Tech have avoided Web pages because of the perceived difficulty in their use. However, based on CoWeb activity in the school in the last year we know have CoWebs being used in eight different classes, excluding those used by the authors of this paper (see question 9 in Table 1.). While much of the use of the CoWebs is non-collaborative, the general response from the chemical engineering faculty has been extremely positive. This ease-of-use presumably frees faculty from the time consuming task of Web page maintenance may

Table 1. Distribution of Student Survey Responses
(Results are a percent out of a total of 25 responses)

#	Survey Question	1	2	3	4	5	mean
1	I read the CoWeb regularly	4	16	8	44	28	3.76
2	I use the Web or Internet regularly	0	4	4	12	80	4.68
3	I use email regularly	0	4	0	8	88	4.80
4	I find it useful to study with others, in general	4	12	20	32	32	3.76
5	I enjoy group projects	4	12	24	24	36	3.76
6	I use email to communicate with members of my group in group project.	0	0	8	16	76	4.68
7	I find the material posted by the instructor on the CoWeb useful	0	0	20	40	40	4.20
8	I find the material posted by the other students on the CoWeb useful.	4	0	12	64	20	3.96
9	I have used the CoWeb in other classes	32	12	4	12	40	3.16
10	The CoWeb is primarily an information resource	0	4	24	44	28	3.96
11	The CoWeb is helpful for sharing ideas and collaborating with others	8	4	12	40	36	3.92
12	I found the CoWeb useful in collaborating with others	8	4	16	48	24	3.76
13	I print reference material on the CoWeb that was posted by the instructors	4	4	0	20	72	4.52
14	I print material posted on the CoWeb by other students	28	28	20	16	8	2.48
15	I found the CoWeb useful in the Virtual Lab Project (filter press)	0	8	20	48	24	3.88
16	I found the CoWeb useful in the Design-Analysis Project	8	16	16	24	36	3.64
17	I found the CoWeb useful for the final exam review	4	0	8	32	56	4.36

produce some of the "Teacher Inventiveness" that is associated with the CoWeb [15].

Student comments were consistent with the numerical data above. In answering the question "Did you find the CoWeb useful?," 24 out of 25 students responded yes. When asked to explain why they did or did not find the CoWeb useful, more students addressed the ease with which information was exchanged, than the benefits of collaboration.

After transforming the data to zero mean and unit variance, we constructed the covariance matrix for the numerical survey responses. Table 2 lists all the covariances whose absolute value was greater the 60% of the unit variance of the variables. Most of these high covariances can be easily explained by clear similarities in the questions and they simply serve as a self-consistency check. However, the high covariance between question 4 ("I find it useful to study with others, in general") and 11 ("The CoWeb is helpful for sharing ideas and collaborating with others") suggests that the students most likely to collaborate are the students most likely to work with each other anyway.

The linear correlation between the numerical results, from these two questions, are shown in Figure 2. While there is significant error in the fitted intercept, the 90% confidence interval for the slope is relatively narrow. The fact that zero is well outside this range indicates that the positive correlation of these two questions is statistically significant. However, given the small sample size, this only suggests that the two are related. Note that the lowest values for question 11 also had a low numerical response to question 1 ("I read the CoWeb regularly").

The correlation in Figure 2 suggests that students who naturally prefer working together with other students will be predisposed to collaboration, CoWeb-based or otherwise. Felder and Silverman have categorized common learning styles among engineering students [16]. An inclination to work together with other students makes one an "Active" as opposed to "Reflective" learner [17]. Active learners tend to retain information by doing something active with it such as discussing it with or explaining it to others. Although no large-scale study has been carried out, Felder believes that most engineers are Active Learners [16]. Therefore collaboration via the CoWeb may positively impact engineering education by addressing a common learning style among engineering students. Although no quantitative conclusion can be made from our data, the correlation above suggests that students that do possess this attribute of Active Learners will find CoWeb collaboration beneficial.

C. Observations on Project Data

While no analysis was carried out for the other two collaborative projects, they did provide some rather interesting anecdotal results. Despite the positive perception of the CHE4200 collaborations, the students were not particularly enthused about the virtual filter lab. Although anecdotal, more enthusiasm was noted for the other two collaborative projects: modeling of transdermal drug delivery and modeling of student weight as a function of numerous student-generated variables. We attribute this increased enthusiasm to the use of relevant and realistic data. The students knew that the data for the simulated filter lab were stochastically simulated data. While the results reflected reasonable values of parameters, taken from actual laboratory data, they had no significance other than providing a test of the student's ability to carry out data analysis. In contrast to this, students in the CHE4400 class were aware that this transdermal data was an area of active research with obvious medical benefits. Students in the MATH2602 class found the data being correlated to student weight very interesting, because it was relevant to the students. Numerous positive comments on this project were collected by the instructor including:

> *"It is kind of amazing that when you do plug in the numbers of your size, age, etc. that it does work out. In our case the number of pounds was within 3-6 each time."*

> *"The project was interesting because it applied information such as the amount of time a person spends studying calculus to their weight. We actually didn't*

Table 2. Pairs of Survey Questions with Highest Covariance

Question 1	Question 2	Covariance §	Comments
11	12	0.918	obvious correlation of survey questions
4	11	0.769	those who study in groups collaborate using CoWeb
4	5	0.762	those who study together typically enjoy group projects
8	11	0.748	those who find CoWeb info. useful use it in collaboration
4	12	0.715	questions 11 and 12 are similar
1	11	0.678	those who collaborate on CoWeb must read it
3	6	0.659	those who use email also use it for group communication

§ Relative to unit variance for all data with zero mean and unit variance

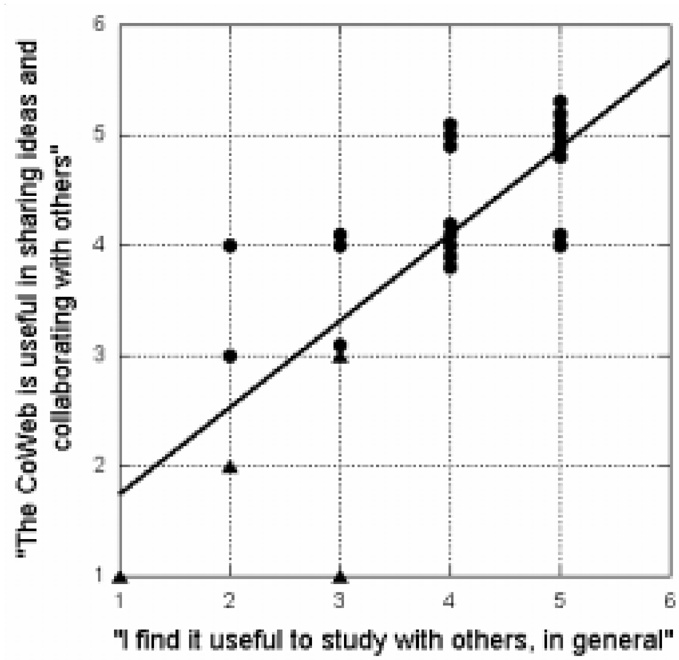

Figure 2. Plot of numerical answer to question 11 versus that of question 4. The response data (filled circles and triangles) are randomly offset in the vertical direction to illustrate where multiple points lie. The 90% confidence intervals on the slope and intercept of the linear regression fit (solid line) are 0.784 ± 0.239 and 0.973 ± 0.938 respectively. The triangles are those responses whose answer to question 1 ("I read the CoWeb regularly") were less than three.

see the correlation between those values, but surprisingly enough we did see a relationship between the amount of hours a person spends a week exercising to their weight."

"The most interesting aspect of the project was the real life application of the work we are doing in class."

Upon analyzing the two separate equations we found for men and women, we noticed some interesting differentiating features in the equations. …We concluded that an hour of weekly exercise will impact a woman's weight more so than that of a man's just through analysis of the equations we found. That was pretty neat."

"During this project, we learned about applying our knowledge of linear algebra to an interesting real world application. … It was interesting to see that we could derive a useful formula using seemingly unrelated data. We think our group threw off the data due to our ridiculous numbers for hours of swimming exercise".

From these anecdotal observations we hypothesize that projects involving data that is realistic and, even more importantly, relevant will better motivate that student. We hope to test this with future investigations.

IV. Summary

As more industrial design occurs in an on-line collaborative fashion, using the CoWeb to facilitate collaboration in engineering and science classes can reinforce a valuable workplace skill. Given the small size of the class studied, we cannot make unequivocal statements regarding the results of our investigation. However, the results do suggest the following:

- Projects integrated into the course that provide a benefit for collaboration appear to induce collaboration with the CoWeb.

- Simply sharing project results on the CoWeb is insufficient to induce collaboration; some activity is required to drive the class to collaborate thereby avoiding a variation of the "Prisoner's Dilemma." The CoWeb could be used to set up an exchange forum whereby inaccurate results are challenged and students receive a grade bonus for such challenges, but no penalty for learning from such challenges.

- Students most likely to engage in collaboration are those predisposed to an "Active" learning style, which may be common among engineers.

- Projects that use realistic data that is relevant to the student will better motivate the student.

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[17] The on-line survey to determine learning styles from Felder and co-workers is available at <http://www2.ncsu.edu:8010/unity/lockers/users/f/felder/public/ILSpage.html>; All of the questions that indicate a tendency to prefer working in groups are associated with being an "Active" learner.

Authors' Biographies

Mark Guzdial is an Associate Professor in the College of Computing and director of the Collaborative Software Laboratory at Georgia Tech. Dr. Guzdial research involves numerous areas of educational computing, and his work in developing the CoWeb has facilitated its use throughout the Georgia Tech campus.

Pete Ludovice is an Associate Professor of Chemical Engineering at Georgia Tech his research involves the application of molecular simulation to a number of areas in polymeric materials and bioengineering. He has designed or redesigned several courses on applied engineering and he uses the CoWeb liberally in his classes to promote collaboration and student-centered learning.

Tom Morley is a Professor of Mathematics at the Georgia Institute of Technology. He has utilized educational technology in a number of math classes, and has co-authored two books of projects (in Mathematica) that are Science based projects designed for the use of students in Calculus and Linear Algebra courses. Dr. Morley oversees CoWeb activities in the School of Mathematics.